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Improvement of Fatigue Strength of Arc Welded Joints Using High Strength Steel Sheets for Automobile Chassis Members

Shinji KODAMA* Kazuki MATSUDA Yoshinari ISHIDA Masahiro OGAWA

Abstract

Recent research progresses on the fatigue strength of arc welded joints using high tensile strength steel sheets are described, focusing on automotive chassis members. First, the effects of the high strength welding wire on fatigue strength were examined by the bending fatigue test. The results confirmed that increase of the welded metal strength associated with the high strength wire suppresses the crack in the welded metal around the toe portion, and improves the fatigue strength of welded joints. Second, fatigue strength between fillet lap joints and butt joints was compared by the tensile load fatigue test. The fatigue strength of butt joints increases two-fold more that that of fillet lap joints, while fillet lap joints and half penetration butt joints on which the root portion cracks generated remained impervious to the effects of high strength welding wire. Finally, welded joints with the stiffening bead were proposed as a countermeasure for improving fatigue strength including the root portion, and its potential for stress reduction and the increasing of fatigue strength were indicated.

1. Introduction

In the automobile industry, the reduction of body weight is becoming increasingly essential from the viewpoint of reducing carbon dioxide emission, and the demand for the application of high strength steel material to reduce the thickness of steel sheets is growing. For automobile members, relatively thick steel sheets are used, and arc welding is used as a jointing method in many cases.¹⁾ The reasons for this are: the welding method secures the strength and rigidity of members with ease by means of continuous welding, provides one-sided welding appropriate for manufacturing closed section members, allows for generous gap tolerance between steel sheets, and realizes the selection of welding wire most suitable to the strength and compositions of the base metal. However, as stress tends to be concentrated inevitably at the arc welded parts of a structure, welded parts of chassis members subjected to repetitive loading tend to generate fatigue cracks.

Research on the fatigue strength of the welded structure of thin steel sheets such as those of automobiles is conducted by the Society of Automotive Engineers of Japan, Inc.,²⁾ and the method for predicting the fatigue strength of the most frequently used joints of automobile members has been studied by computer aided engineer-

ing (CAE). On the other hand, methods for improving the fatigue strength of welded parts have been developed mainly in the fields of bridge construction and shipbuilding, and for such heavy plate structures, Ultrasonic Impact Treatment (UIT) to obtain compressive residual stress³⁾ and low transformation temperature welding material⁴⁾ are practically used. Further, from the viewpoint of improving the bead configuration of steel sheet welded joints, steel material compositions and welding wire compositions are being studied, and the addition of Si is reported to be effective in flattening welded beads, and in suppressing under cut.⁵⁾ Furthermore, regarding the jointing process, processes to realize welded beads of gradual configuration have been developed, and plasma arc hybrid welding technology⁶⁾ and "MX-MIG" process⁷⁾ are proposed as jointing processes for automobiles.

Thus, the importance of fatigue strength of the arc welded parts of automobile members has long been recognized, and various countermeasure technologies have been developed. However, steel sheets of 440 MPa grade and 590 MPa grade are used mainly at present,⁸⁾ with steel sheets of 780 MPa grade increasingly used in part. As cold rolled steel sheets of 1.2 GPa and hot-stamping steel sheets of 1.5 GPa have already been applied to body structural mem-

^{*} Senior Researcher, Dr. Eng, Welding & Joining Research Lab., Steel Research Laboratories 20-1 Shintomi, Futtsu City, Chiba Pref. 293-8511

bers,⁹⁾ delay in the application of high strength steel sheets cannot be denied. To promote the application of high tensile strength steel to crucial safety-related automobile chassis members, it is necessary to supply welded members that have a higher reliability than previously required. Therefore, for the welding process to manufacture such members, it is important to develop a method that is practically applicable to the actual production process. Against this background, in this article, the results of a recent study on high strength welding wire, and on joint structure that was conducted to improve the fatigue strength of arc welded joints of automobile chassis members are summarized.

2. Improvement in Fatigue Strength of Welded Joints by Applying High Strength Welding Wire

For automobile chassis members, steel sheets of 440 MPa-780 MPa grade are used, and welding wire of mild steel with tensile strength of approximately 490 MPa grade is used for assembling in many cases.8) Figure 1 shows an example of the static strength of arc welded joints of base steel sheets of 440 MPa-980 MPa grade. For each steel sheet, a fillet lap joint was prepared using welding wires of different strengths, and tensile share tests were conducted. The joint strength is expressed by the stress of fracture load divided by the sectional area of the base metal. As indicated by the figure, for 440 MPa-780 MPa grade steel sheets, joint strength equivalent to that of base metal strength is obtained even when 490 MPa grade mild steel wire is used. In addition, even in the case of 980 MPa grade steel, welded metal fracture is avoided with 780 MPa grade welding wire. Generally, in the arc welding of steel sheets with only one welding path, approximately 30-40% of the base metal compositions are assumed to diffuse to the welded metal, and an increase in the strength of welded metal owing to the alloy metals of the base metal is expected. Thus, from the viewpoint of static strength alone, the use of high strength welding wire matching the strength of the base metal is unnecessary.

In contrast, few studies have been conducted on the effect of high strength welding wire on fatigue strength of the welded part. In **Fig. 2**, configuration of the fillet lap joint that is frequently used in chassis members is shown. Fatigue cracks are assumed to be generated at the weld toe and the weld root, and tensile residual stress, stress concentration coefficient and the strength of the crack generating part are assumed to exert influence on fatigue strength. However, countermeasures so far discussed including the aforementioned fatigue-strength improving measures are aimed at the reduction of



Fig. 1 Static strength of arc welded joints

residual stress and/or stress concentration, and there has been almost no study conducted on the effect of the strength of welded metal on fatigue strength. Therefore, the feasibility of improving fatigue strength of the welded part by applying high strength welding wire was studied.¹⁰

A hot-rolled steel sheet of 780MPa grade (sheet thickness 2.3 mm) was used for the test, and three types of welding wires. each having different strength, were used. In Table 1, the chemical compositions and mechanical properties of the deposit metal of the wires are shown. Wire A and Wire B are welding wires for mild steel and Wire C is for 780 MPa grade steel. Welding was conducted using the pulse MAG welding method under the conditions of a shielding gas of Ar+20%CO₂, welding current of 190A, arc voltage of 24.5 V and welding speed of 0.8 m/min. Figure 3 shows the shape of fatigue test specimens. To obtain the fatigue strength at the weld toe by the test of the fatigue limit under completely reversed plane bending, opening of the weld root on the back side was closed by applying restraining welding after the fillet lap welding that determines the examination point was applied. The displacement-control bending fatigue test (bending load R=-1) was conducted with a cyclic frequency of 25 Hz. The test was terminated when the torque decreased by 40% or when the number of cycles reached 2×10^6



Fig. 2 Configuration of fillet lap joint

Table 1 Properties of welding wire

Wire No.	Chemical compositions (mass%)				Mechanical properties		
	С	Si	Mn	Others	YP(MPa)	TS(MPa)	EL(%)
Wire A	0.09	0.14	0.94		380	470	33
Wire B	0.07	0.61	1.21		460	570	30
Wire C	0.07	0.27	1.37	Ni, Cr, Mo	770	870	19

Results of deposit metals in Ar+20%CO₂ shielding gas YP: Yield point, TS: Tensile strength, EL: Elongation



without a decrease in torque.

Figure 4 shows the macroscopic photographs of cross sections of the welded part. There is no difference in the welded bead configuration regardless of the type of welding wire used. The radius of curvature at the weld toe that causes stress concentration is approximately 1 mm, and the stress concentration coefficient in the bending test judged from the radius of curvature at the weld toe is approximately 1.3.

Figure 5 shows the results of the fatigue test. The fatigue strength of the welded part increases as the wire strength, namely the welded metal strength, is increased. Different from 210 MPa with Wire A, the fatigue limit becomes 280 MPa with Wire C, and the effect of improving fatigue strength by approximately 30% was obtained by using a high strength wire.

To examine the effect of welded metal strength on crack generation behavior, cross sections of fractured test specimens were observed. **Figure 6** shows the cross sections of the welded part of fractured test specimens. With macroscopic observation, although cracks of all test specimens look as if they are being generated at the weld toe, namely the boundary between molten and unmolten parts,



Fig. 4 Cross sections of welded part



Fig. 5 Results of fatigue test

when the crack section is magnified and observed, with Wire A and Wire B, cracks are generated at the welded metal; when Wire C of high strength is used, a crack is generated in the heat affected zone (HAZ) adjacent to the weld toe. The observed cross sections may not show the crack-generating position but may show the crack generation and propagation part as a whole. Therefore, although it is not appropriate to draw definite conclusions here, it is considered that repeated plasticization at the crack-generating part was suppressed by the strength of welded metal that increased by the application of high strength wire, and the fatigue strength of the welded joint was improved accordingly.

As one of the reasons for crack that tends to be generated in the welded metal, not only the macroscopic configuration of the weld toe but also the micro irregularities on the bead surface are considered to exert influence.¹¹⁾ **Figure 7** shows the results of observation of the surfaces of welded beads after the fatigue test by Scanning Electron Microscope (SEM). A crack is generated along the wavepattern called a ripple. Therefore, for a more in depth understanding of the fatigue phenomena of welded parts, analysis from a higher microscopic viewpoint is considered to be important.

So far, as a means to improve the welded part fatigue strength, the effect of high strength weld wire was described. According to traditional knowledge, even though the strengths of steel material and welding wire are increased, the fatigue strength of the welded part was assumed not to increase. However, the possibility that increasing the strength of the welded part where a crack is generated



Fig. 6 Cross sections of fractured specimen



Fig. 7 Fatigue crack from micro irregularities in welded bead



Fig. 8 Cross sections of fractured specimens

is effective for improving the fatigue strength of the welded joint was suggested. In this regard, the following reasons are considered: in thin steel sheet welded joints, structural stress concentration is reduced owing to the effect of reducing sheet thickness, and residual stress is small as out-of-plane deformation takes place with relative ease. Therefore, if weld bead configuration that can reduce the fluctuation of stress concentration is stably maintained in weld beads, fatigue strength may be further improved along with the increase in strengths of the steel sheet and welding wire. In this evaluation, a test was conducted pertaining to cracks assumed to be generated at the weld toe; however, in actual members, cracks are considered to be generated at various welded positions. Therefore, understanding the performance of actual members is indispensable.

3. Effect of Joint Type on Fatigue Strength

For automobile chassis members, the fillet lap joint is widely used to take advantage of its stability in welding work and its ability to absorb the fluctuation of the configuration of parts developed in press-forming. Accordingly, as described in the preceding section, the fatigue strength of the welded part is evaluated based on the fillet lap joint in many cases. However, when a tensile load acts upon a fillet lap joint, the coefficient of structural stress concentration at a welded part increases due to displaced thickness centers. On the other hand, in a butt joint, the stress concentration at a welded part is alleviated, and the fatigue strength is predicted to improve accordingly. Therefore, in this section, fatigue strengths of fillet lap joints and butt joints are compared by the tensile fatigue test in which a load is applied in the axial direction.¹²

Hot-rolled steel sheets 2.6mm in thickness of 440 MPa grade and 780 MPa grade, and welding wires of 490 MPa grade (Wire B) and 780 MPa grade (Wire C) were employed. The respective wire is the same as the one shown in Table 1. Two types of butt joint, one with half penetration and the other with full penetration, were prepared. This is because in view of the difficulty of producing full penetration butt joints in a stable manner in the actual production of members, and therefore taking into consideration that welding conditions fluctuate, butt-welded test specimens with penetration of half of the sheet thickness were also prepared and evaluated additionally.

JIS No.13 B test specimens were taken from the welded test

specimens, and used for the test. A load-control tensile fatigue test (tensile load R=0.1) was conducted with a cyclic frequency of 25 Hz, and the test was terminated when test specimens fractured, or when the number of cycles reached 2×10^6 .

Figure 8 shows examples of the photographs of cross sections of fractured test specimens. Different from the results of the bending fatigue test as shown in the preceding section, in the fillet lap joint, a crack was generated at the weld root and propagated in the direction of thickness within the welded metal. In the case of the half penetration butt joint, a crack was generated at the bottom of the penetrated metal on the butt surfaces of steel sheets, and propagated through the welded metal. On the other hand, in the case of a full penetration butt joint, a crack was generated at the weld toe on the backside, and propagated to HAZ. Additionally, another crack was observed at the weld toe in the test specimens of the fillet lap joint of 440 MPa steel with 490 MPa grade wire; however, no cracks were confirmed at the weld toe in the test specimens of the fillet lap joint of 780 MPa steel with 780 MPa grade wire.

Figure 9 shows the results of the fatigue test for the following cases: 440 MPa steel with 490 MPa grade and 780 MPa grade wires, and 780 MPa steel with 780 MPa grade wire. The result of the case of 440 MPa steel shows that the fatigue strengths of the half penetration butt joint and the fillet lap joint are almost the same whereas the fatigue strength of the full penetration butt joint was 2.5–3 times higher. As, even in the half penetration butt joint that was assumed for fluctuation of the welding condition and additionally prepared, fatigue strength equivalent to that of the fillet lap joint is obtained, and as, in the full penetration butt joint, excellent fatigue strength is obtained, the butt weld joint is an effective jointing style for welded part fatigue strength.

On the other hand, when the effects of the steel sheet and welding wire are compared, the fillet lap joint and half penetration butt joint exhibit similar characteristics of Stress amplitude Number of cycles (SN) regardless of the types of steel sheet and welding wire. However, the fatigue strength of the full penetration butt joint increases as the strengths of the steel and the wire are increased. **Figure 10** shows the hardness distribution of the full penetration butt joint. Hardness at the boundary between the molten and unmolten parts that corresponds to weld toe is increased by increasing the







Fig. 10 Vickers hardness distributions of welded joint

strengths of the steel sheet and welding wire, and in the case that a crack is generated at the weld toe, increasing the strength of the crack-generating part is effective for increasing fatigue strength. This view agrees with the conclusion in the preceding section.

However, in the case of a crack being generated at the weld root, the high strength steel sheet and welding wire had no effect on the improvement in fatigue strength. Then, based on the cross section configurations of joints, various joint configurations were reproduced, and 2D FE analysis was conducted. Assuming that all materials including base metal and the welded part are homogeneous, and inserting Young's modulus of 206000 MPa and Poisson's ratio of 0.3, the state of stress when a tensile load of 50 MPa was applied to the end of the steel sheet was analyzed. Figure 11 shows the stress distribution in the direction of the tensile load. The stress-concentrated position is confirmed to agree with the fracturing position of the respective joint. Further, maximum stress in the direction of loading in the fillet lap joint was 306 MPa at the weld root, and in the full penetration butt joint, it was 84 MPa at the weld toe on the backside; in the half penetration butt joint, it was 270MPa at the face-to-face position of the butts. Where a crack was generated in the fillet lap joint and half penetration butt joint, the maximum stress was three times higher than that of the full penetration butt joint, and this agreed with the extent of deterioration of fatigue strength on the whole.

So far, the effect of joint style on fatigue strength has been discussed. As a result, it was confirmed that butt joints, different from fillet lap joints, are very effective from the viewpoint of fatigue



Fig. 11 Estimated stress along load direction in welded joint

strength. However, as it is difficult to produce butt joints stably with current arc welding, hereinafter, integrated study on forming technology to improve the accuracy of parts of members and the jointing technology such as laser arc hybrid welding are required. In the case of a crack being generated at the weld root, the effect of improving fatigue strength was not obtained even if the strengths of steel sheet and welding wire were increased. This is because the stress concentration coefficient at the weld root is very high as compared with the one at the weld toe, and generation and propagation of cracks take place mainly in the weld metal. Presently, study on fatigue characteristics of the weld root is insufficient, and detailed analysis is required.

4. Improvement in Fatigue Strength of Welded Joint with Stiffening Bead

4.1 Study of fillet lap joint

In the preceding section, fatigue strength in the case of a crack being generated at the weld root was evaluated. Generally, automobile members are designed so as to avoid fatigue crack at the weld root, and studies so far conducted on improving fatigue strength of the welded part have mostly focused on countermeasures for crack generation at the weld toe. However, to continuously meet the ever growing stringent demands for reducing steel sheet thickness, meas-

ures for improving the fatigue strengths of the welded part including weld root are considered to be important.

Figure 12 shows stress distributions and the states of deformation along the loading direction in the fillet lap joint when an axial load is applied. Displacement in the thickness direction is exaggerated in order to make it easier to observe the state of deformation. As a load is applied, angular deformation takes place in the welded part and the stress concentration coefficient increases. In addition, in the case that a gap is set between the upper sheet and the lower sheet, assumed for fluctuation of joint configuration, the angular deformation becomes larger, and the stress concentration coefficient at the weld root increases in particular. Therefore, improvement in fatigue strength of the welded part including weld root is considered possible by suppressing the angular deformation when loaded. Then, a bead that crosses the weld line (hereinafter referred to as stiffening bead) was additionally provided, of which the effect on fatigue strength was evaluated.¹³

Hot-rolled steel sheet SPH440 2.6 mm in thickness was used, and a fillet lap joint was prepared by the pulse mag welding method using a welding wire for 490 MPa steel. The joint configuration is shown **Fig. 13**. The gap between the upper and bottom sheets was set at 0 mm and 1 mm, and in the center part of the steel sheet 60 mm in width, a fillet bead 45 mm in length was provided. Three stiffening beads as shown in **Fig. 14** were compared. In (a), a stiffening bead 50 mm in length, starting at the fillet bead, is provided on the lower sheet. In (b), a stiffening bead starting at the fillet bead is provided on the upper sheet. In (c), H-shape stiffening beads 25 mm in length were provided so as to traverse the starting point and the termination point of the fillet bead, respectively. Further, at the starting point, a bead tends to be of convex configuration, and increase in



Fig. 12 Stress distributions along loading direction in fillet lap joint

the stress concentration is considered. Therefore, for stiffening of the upper sheet and the lower sheet, the stiffening bead welding was started at the fillet bead so as to provide a crater with gradual configuration on the steel sheets.

By using these test specimens, a load-control tensile fatigue test (tensile load R=0.1) was conducted. The test was terminated when test specimens fractured, or when the number of cycles reached 2×10^6 . Figure 15 shows the appearances of fractured test specimens. In any case, the test specimens fractured at the weld toe or at the weld root of the fillet bead, and the stiffening bead did not generate cracks by itself. In the case of 0mm of the steel sheet gap, the joint without the stiffening bead fractured at the weld toe, and in the joint with the lower sheet stiffening, cracks disappeared. With upper sheet stiffening, the joint fractured at the weld toe, and with H-shape stiffening beads, the joint fractured at the weld root. Thus the fracture mode varied. On the other hand, in the case that a gap of 1 mm is set between the steel sheets, fracture generated at the weld root was confirmed regardless of the presence of the stiffening bead. As Fig. 12 suggests, the presence of a gap between the steel sheets increases the stress concentration coefficient at the weld root.

Figure 16 shows the results of the fatigue test. The result of the test in the case of 0 mm gap between the steel sheets shows that the timewise fatigue strength of the fillet bead with the stiffening bead on the upper sheet is slightly higher than that of the fillet bead without the stiffening bead, and the effect was small. Conversely, H-shape stiffening beads and the stiffening bead on the lower sheet increase fatigue strength significantly. In particular, the fillet bead with a stiffening bead on the lower sheet did not fracture within this load range, and the effects of increasing the fatigue life by approximately 5 times and the fatigue strength at the 2 millionth cycle by approximately 2 times were obtained as compared with the case of the fillet bead only. From the result of the case with a steel sheet gap of 1 mm, deterioration in fatigue strength in any joint due to the presence of a gap was confirmed; however, it was also confirmed that the stiffening bead on the lower sheet and the H-shape stiffening



Fig. 13 Configuration of fatigue test specimens



Fig. 14 Configurations of stiffening beads



Fig. 15 Appearances of fractured specimens





beads were effective.

To compare the effect of improving fatigue strength of the respective stiffening beads, in **Fig. 17**, the fracture cycles and the fracture positions with the load amplitude of $\Delta P=9kN$ are presented. "T" in the figure denotes weld toe fracture, "R" denotes weld root fracture, and "T&R" denotes the mixed state of both. In the case of the gap of 0 mm, the fillet bead with a stiffening bead on the lower sheet exhibited fatigue strength higher than that of the fillet bead without the stiffening bead by more than 5 times, and the H-shape stiffening beads, by 3.5 times. When the gap becomes 1 mm, although the fracture life is shortened relatively, fatigue life was improved 4 and 5 times by the stiffening on the lower sheet and Hshape stiffening. As such a gap between steel sheets is considered to appear frequently in actual production, stiffening on the lower sheet and H-shape stiffening that have been proven as effective in the case of the gap of 1 mm are considered to be useful.

Figure 18 shows the results of FE analysis conducted to confirm the effectiveness of the stiffening beads. The results show the stress



distribution in the direction of a tensile load when a stiffening bead is provided on the lower sheet. Similarly to the case shown in Fig.



Fig. 18 Effect of stress reduction by stiffening bead

12, assuming that all materials including base metal and the welded parts are homogeneous, and inserting Young's modulus of 206000 MPa and Poisson's ratio of 0.3, the stress distribution in the direction of loading when a tensile load of 50 MPa was applied to the end of the steel sheet was analyzed. When the stress distribution on the welded bead surface is compared as to the presence and absence of a stiffening bead, the stress at the weld toe of the fillet bead is reduced by providing a stiffening bead.

Furthermore, when the stress distribution on the cross section of the weld-starting position where fatigue crack tends to be generated is observed, the stress concentration coefficients of both the weld root and the weld toe are decreased by the stiffening bead. In this analysis, as the length of the stiffening bead is set at 25 mm, half of the length of 50 mm of the stiffening beads employed in the experiment, it is considered that although the effect of decreasing the stress concentration coefficient is smaller, this result illustrates the effectiveness of the stiffening bead qualitatively. The reason for the failure to obtain the effect of improving fatigue strength with a stiffening bead on the upper sheet, and the reason for the effectiveness of reinforcing the fillet bead at its starting and termination positions with H-shape stiffening have not been clarified sufficiently. Therefore, they remain as future study subjects.

4.2 Study on T shape fillet joint

Based on the findings about the stiffening bead in the fillet lap joint, the effect of the stiffening bead for the T shape fillet joint, similar to the one used in actual members, was studied.¹⁴⁾ As the subject member for study, taking into consideration the arc welded joint that is widely used in automobile production,¹⁵⁾ the structure of a hat-type base member that is jointed with a bracket member via a T shape fillet joint was employed. In the fatigue test, the base member was restrained by a gate-type jig, and a repetitive load in the vertical direction was applied to the bracket member. **Figure 19** shows the analysis model and the restraining condition. The field of analysis is the 1/2 model of the base member, bracket member and the pin for loading, with symmetricity taken into consideration. The



Fig. 19 Simulation model of T shape fillet joint

bracket member and the base member were assumed as elastic bodies having Young's modulus of 205800 MPa and Poisson's ratio of 0.3, while the loading pin was assumed as a rigid body.

The model configurations of the welded beads between the bracket member and the base member were produced based on the cross-section macroscopic photographic images of the actual welded parts. The fatigue crack is generated at the edge of the weld bead of the bracket member. Therefore, through detailed observation of the cross sections of the welded parts like those shown in **Fig. 20**, precise reproduction of the actual welded bead configuration was investigated.

In the fatigue test and the FE analysis, the case without a stiffening bead (standard configuration) and the case with a stiffening bead provided at the fillet bead at the bracket member edge were compared. **Figure 21** shows the crack positions after the fatigue test, and the simulation result of the distribution of the maximum main stress when a load is applied in the upward direction. In the standard con-

figuration, the maximum main stress becomes high at the fillet bead at the bracket member edge ((A) in the figure), which is confirmed to agree with the crack-generating position. Additionally, in the case that a stiffening bead is provided, the maximum main stress at the position of stress concentration in the standard configuration grows smaller, and the stress at the front edge of the welded part ((B) in the figure) becomes higher. A crack is generated around the top surface of the fillet bead in the fatigue test, and good agreement with the result of analysis is confirmed.

Next, the maximum main stress at the stress concentration position (A) in the standard configuration and the stress at the front edge position (B) with a stiffening bead were compared. The stress at the front bead edge position (B) with a stiffening bead is lower than that of the maximum main stress at the stress concentration position (A) in the standard configuration. Further, according to the result of the fatigue test separately conducted, fatigue life is extended when a stiffening bead is provided, and both results agreed with each other in this regard.

Here, the effectiveness of a stiffening bead as a means for im-



Fig. 20 Detailed observations of top end of welded bead

proving the fatigue strength of the welded part including the weld root was confirmed. By providing a stiffening bead, the rigidity around the welded part is enhanced, and the local stress concentration coefficient of the welded part is reduced accordingly. This technique adds a welded bead several tens of millimeters in length to a joint in conventional welded structure members where the generation of cracks is apprehended. This is a technique for improving fatigue strength while minimizing the load to production to the extent possible. However, in actual members, spatial confinement when providing a stiffening bead and change in the state of stress distribution due to the addition of a stiffening bead are apprehended. There is a concern that evaluation in trial production will have to be made on a trial-and-error basis. To eliminate such apprehension, we are determined to develop a systemized technology in order for the stiffening bead technique to be incorporated into the design and used comprehensively.

5. Conclusion

In the pursuit of further lightweightness of automobile chassis members, subjects and the results of the latest study on the improvement of fatigue strength of the arc welded joint were described. To continuously cope with the ever growing demand for higher strength and further reduction in sheet thickness, it is necessary to provide a welded joint having higher reliability than ever before, and not only material technology but also reliability-enhancing technology with improvement in the configuration of members are required. Furthermore, in the welding of chassis members, hydrogen embrittlement in high strength steel sheets and securing of corrosion-resistance in thinner steel sheets¹⁶ are considered to be crucial issues.

In the actual production of chassis members, from the viewpoints of wide-ranging adaptability to various jointing types, and robustness that allows for errors that take place when assembling press-formed parts to a member, arc welding is widely used, and shall continue to remain in use in that capacity for a considerable period of time in future. However, if the application of low-heat-input laser welding or laser arc hybrid welding becomes possible, the



Fig. 21 Relationship between crack positions and stress concentration parts

production of members further excellent in fatigue strength and corrosion resistance is considered feasible. Post-treatment technologies such as UIT and shot peening will become an effective means for improving fatigue strength by applying compressive residual stress, and for improving post-coating corrosion-resistance by removing scale. We are determined to continue hereinafter our efforts to realize highly reliable joints by taking advantage of the merit of arc welding, and contribute to achieving further lightweightness of automobiles by developing new jointing technology, and proposing new production methods based thereon.

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Shinji KODAMA Senior Researcher, Dr. Eng. Welding & Joining Research Lab. Steel Research Laboratories 20-1 Shintomi, Futtsu City, Chiba Pref. 293-8511



Yoshinari ISHIDA Researcher Welding & Joining Research Lab. Steel Research Laboratories



Kazuki MATSUDA Dr. Eng. Welding & Joining Research Lab. Steel Research Laboratories



Masahiro OGAWA Senior Researcher Materials Reliability Research Lab. Steel Research Laboratories